McKinsey & Company

Operations Practice

The future of manufacturing

A small number of factories worldwide have successfully combined automation, artificial intelligence, and the Internet of Things to achieve game-changing productivity gains. How did they do it, and what can we learn?

March 2019

In this episode of the *McKinsey Podcast*, Simon London speaks with McKinsey senior partner Katy George and partner Enno de Boer about the future of manufacturing—think digital and advanced analytics, not robots.

Podcast transcript

Simon London: Hello, and welcome to the *McKinsey Podcast*, with me, Simon London. The future, they say, is already here. It's just not evenly distributed. Well, this pretty much sums up the current state of manufacturing. Some factories are indeed moving at pace into the future. They're combining automation, artificial intelligence, the Internet of Things [IoT], and more to fundamentally change how they operate. And yet the majority of manufacturers are struggling to deploy these technologies at scale. To understand why, I sat down in New Jersey with McKinsey partners Katy George and Enno de Boer. Enno and Katy are fresh from a joint research effort with the World Economic Forum to track down and understand these "lighthouse" manufacturers, beacons of best practice in the emerging fourth industrial revolution. Katy and Enno, thanks for being here. Welcome to the podcast.

Enno de Boer: Very happy to be here.

Katy George: Excellent to be here. Thanks for having us.

Simon London: Enno, you've just come back from a little bit of a world tour looking at some of these manufacturing plants. When I think about the future of manufacturing, I'm imagining big greenfield operations, lots of robots, not many people. Is that broadly what you find?

Enno de Boer: Actually, it's the opposite. We see that in this industrial revolution, you can build on the existing equipment you have. It's mainly brownfield situations. Look at one of our lighthouses[1]—the Procter & Gamble Rakona plant. That's a site that has been there since 1875.

Simon London: So not greenfield at all. That's about as brownfield as you can get.

Enno de Boer: Well, you can do a greenfield, and you can use the technology in greenfield, but it's very much applicable to brownfield. Sensoring has become so affordable that you can sensor out all the factories with existing equipment and then put the data to work.

Katy George: What I think is very exciting is not only can you think about utilizing existing assets in a new way—but that goes for the workforce as well. How can we utilize an existing workforce and upskill or reskill them to be successful in the new technologies? As Enno said, what we're seeing around the world is that some of the most advanced Industry 4.0 plants not only are using brownfield assets but they're also using their same workforce. The people are learning new skills and working in a new way.

Simon London: OK. So my preconceptions have been thoroughly shattered. We're not talking about big greenfield robotic operations. When you do go into these plants, what are the technologies in play?

Enno de Boer: Let me start with the best-known example: predictive maintenance. That's one use case. There you already see how many technologies come together to innovate the way we do maintenance in the future. And the future is now.

First, you have sensors on machines. They create signals, and IoT connects those into a data lake. Machine-learning algorithms help to dig through all the data and digest it and make meaning out of it. That's the intelligence part.

[1] The term describes facilities so advanced in their use of digital technology, automation, analytics—and robots—that they stand out among their industry peers.

Now we're putting automation in place. This automation is scheduling the maintenance job, and it's ordering all the spare parts that the maintenance engineer needs to do his or her job. The maintenance engineer arrives at the site, has an AR [augmented reality] headset, and gets instructions on how to fulfill the maintenance job. He or she doesn't need a lot of training to do the job. If there's something highly complicated, he or she will call an expert, and it will get fulfilled. Maintenance is done differently than before.

Simon London: Predictive maintenance is a single use case, but it's bringing together different technologies into radically different processes to reach these step changes in performance improvement.

Enno de Boer: Correct. To give you another example, digital performance management is also a highly impactful use case. We all know the dashboards in manufacturing sites. You walk into a site, and today, all of those sites have dashboards. You see some KPIs [key performance indicators] lighting up, et cetera.

That's not digital performance management. What digital performance management is, is that these dashboards get fed by sensors with accurate real-time data. We're not talking in a management meeting anymore about whether this data is true because there's one source of truth. It's in there, it's correct, and it's real time. It's right after the shift, so we can problem solve immediately. Now we want to drill down and understand something. On a fingertip we can drill down into the data, make meaning out of it, and solve a problem, which in the past, would have taken us maybe two weeks until someone came back with an answer. Now we can do it right away. And with it, we have a new level of performance of our management.

Katy George: Another good example is the use of digital standard operating procedures, or digital SOPs, which I think is very exciting. Because, basically, it moves away from the horrible old notebooks that many plants used to have, which would list the different procedures, and people would be trained using them. I have plants where people are trained on hundreds of these procedures, and of course they don't remember all of them. So, SOPs that are on a screen that they can see real time. It's a bit like moving from using a map to using a GPS system.

As you look at the SOPs in real time, if a change happens—to the condition of a piece of equipment—you can change in real time to reflect to the new operating procedures that are required relative to that new condition or to the new task. It's very exciting because it improves people's productivity and it also brings dramatic improvements in the quality.

In many cases, plants will find that human error is one of the most important sources of variability, of deviation, of productivity loss, of any kind of error in the site. So this eliminates human error, because it tells people exactly what they can do. It also dramatically improves the time it takes to get people up to standard performance on a new task.

Simon London: Yes. It's like, to use the math analogy again, you're much less likely to get lost if you've got GPS.

Katy George: That's right.

Enno de Boer: Let me give you one example. Imagine, for commercial airplanes, you do the wiring—a highly complex task. The work instructions are captured in a telephone-book-like work-instruction book. These days, we see that operators get virtual reality, and they get instructions as they go. The result is they don't have errors anymore, and they are much more productive. They like it, because they don't need to do this cumbersome work of looking through the instructions, and then doing something back and forth.

Katy George: Many of our clients have rolled out single technologies around specific kinds of use cases, often because they want to pilot and show the benefit of those single use cases. These lighthouse sites have put together many different use cases. There's not one recipe for which combination they should be. But they put together many, and they're piloting many more. That combination creates a scale effect that transforms the performance of the site, the culture of the site.

Simon London: That's in the research, isn't it? That there seems to be an optimum number of use cases to pursue, and it is a portfolio approach.

Enno de Boer: Yes. We see that around 20 to 30 use cases, applied to one site, creates a transformation of the value.

Bayer, in Italy, was able to increase productivity by 40 percent. The Bosch Wuxi site in China was already operating at 94 percent OEE [overall equipment effectiveness] and was able to squeeze out another 6 percent of output in capacity without doing capital investments. These are step-change performance changes.

Katy George: What's important about that—if I can just add to this—is these are not plants that started as laggards and just used digital and automation to catch up. What we're seeing is some of the very best plants across sectors finding that they can go beyond what they were already excellent in—in terms of lean-manufacturing capabilities, et cetera—and build on those, and by using these new technologies, take their performance to a whole new level.

The performance improvement is not just along one dimension. It's not just that productivity improves. It's that productivity and quality improve. Productivity and flexibility or agility improve. What we're seeing, in both the lighthouse sites but more broadly in our research, is that this is a winner-takes-all kind of environment.

A lot of our clients are asking us, "Isn't it OK just to be a fast follower? There's such uncertainty in the technology." And the answer is, "Probably not." The front-runners get the spoils financially. The ones who have followed struggle to get to the same economic benefit.

Simon London: Do we know why that is?

Katy George: It's because they have repositioned themselves competitively in such a significant way, in terms of cost structure but also in terms of customer experience and flexibility to new demand patterns, and things like that.

Enno de Boer: Let me give you an example. In terms of innovation, UPS together with Fast Radius, they entirely changed the game on spare-parts management. They are not putting spare parts on the shelves, for years. They have 3-D printers in their warehouse locations and send spare parts out on demand. That's changing the game entirely. If you have figured that out at scale, it's very hard to follow.

Simon London: How do you prevent, as a management team, with the arrival of these technologies, making people feel more like a cog in an automated machine? Where they're getting instructions, and they're fulfilling things, but they're under constant supervision, being measured against the benchmarks, standard time, and standard procedures.

Katy George: In a sense, this is a nice progression of what we've seen in manufacturing over the last 50 years. If you go back to the assembly line, that was the worst in terms of being given a specific task, being part of a big machine, and just doing that task repetitively, and not being asked to do anything more than that.

When you get to the Toyota production system in lean, it unleashes human creativity and potential. People still have standard work, and they still have

transactional work, but they're also being asked to continually improve those standards along with their teammates. They have control over the system in that they can pull the Andon[2] cord if there's a problem that needs to be fixed.

Now we're taking that one more step forward: we're going to eliminate some of that standard transactional work and just leave the fun of the Toyota production system in terms of the ongoing continuous improvement, the creativity, et cetera.

I think we should face the fact that, what this will mean, at least in some production environments, is fewer people, because we will automate some of the tasks that people used to do. But for the people who are left, the jobs will be far more interesting, because they will be doing work that is more creative and more relationship based. It will be about them connecting to others and making things happen in the total system. This adds more value and is more fun.

Enno de Boer: At the Schneider Electric site, we saw that operators were able to create their own digital apps that support their work. They're not waiting for cumbersome IT projects that take maybe a year until their problem is solved—and then it's solved in a way that does not fit with how they can and want to do the work. We see a lot of engagement of the operators. They get excited, because they have the tools that they need to do their job in a very good manner.

Simon London: Presumably, this is one of the reasons why companies—that frankly are at the cutting edge of manufacturing in the pre–Industry 4.0 era—could have something of an advantage, because they know how to mobilize the workforce, how to engage a workforce, and how to bring the best out of people, which is part of the game.

Katy George: There's no question. In fact, at some of the roundtables that we've led with manufacturing leaders who've been working on these transformations, you ask, "What's your biggest failure mode?" And they've said, "The biggest failure mode is when we try to digitally transform a site that has not mastered lean." Because not only is the workforce not prepared for this kind of change—but also the processes are not characterized well enough. Things are not under enough control to take full advantage of digital.

Enno de Boer: I agree with Katy. But I would also say, for someone who has not gone through the lean journey, that it's not the time to wait, thinking that you can leapfrog. I talked about digital performance management. You would no longer do the standard performance management. You would put this immediately in place. But Katy is right. A good lean foundation helps you to go through your digital transformation much faster than if you need to, as you transform, also put these basics in place.

Simon London: My second devil's advocate question: people listening to this may be thinking, "Are we being too optimistic about the number of jobs that will be lost or not gained during this transition?" I know you said that people are in evidence in these lighthouse projects. But what's our overall takeaway in terms of the overall impact of this on job growth?

Katy George: I think this is another situation where "winner takes all" is relevant. What we're seeing in our lighthouse sites is that they are rapidly improving their capacity and productivity—and using this so that they can grow, with the same number of people and the same number of fixed assets, which is healthy. What they're seeing is that they're taking more share, if you will. Of course, we're in a demand growth economy right now, so they're growing. When there is an economic downturn, someday, they'll be in a far better position, because they have changed their breakeven point.

[2] Andon is a term used in manufacturing that refers to a system that can alert workers of a problem.

But for companies and for plants that are laggards, there is a serious question about what will happen to them as they try to catch up. Because there is no question that you can do more with fewer people. That will be one of the impacts of the Industry 4.0 revolution.

Enno de Boer: We're concerned about the laggards. That's why we're working with the World Economic Forum. One mission of this work is to say, "How do we make sure that technology gets diffused? How do we make sure that we have inclusive growth?" Because we don't want to see a big displacement. So, as Katy said, the laggards, that's what's concerning us most. It's not only about the laggards as companies but also the laggards in a production network. They will be left behind, and there will be displacement. We want to prepare for that.

Simon London: And, in a production network, that means broadly within a single corporation. Certain plants are left behind. The question is, What happens to them if and when and how there's a downturn? We would concede and agree that there is an impact on the overall number of jobs over time and relative to output. But I think the interesting point is, if you look at these advanced plants today, they are not lights-out manufacturing. They are not robot greenfield sites with no people.

Katy George: They are not lights-out manufacturing. They are places where the role of human beings has increased; they have become augmented: more interesting and more satisfying.

A lot of our research has looked at what the role of manufacturing is on an economy in general and on the global economy. In the 1950s, manufacturing was a very, very important source of jobs, employment, and growth. That's no longer the case. That hasn't been the case for some time. But it is critical to having a disproportionate share on productivity growth in an economy.

Productivity growth is important because that's what drives our standard of living. That's why it's important to have a manufacturing core. Not to create the same kind of jobs that we saw in the 1950s but to drive productivity. Productivity has been stagnant for the last ten years globally. It's a huge problem. This is one of the ways that we can see jump-starting productivity growth in a way that is important for each economy.

Simon London: We've been talking quite a lot about leaders, and laggards, and winner takes all. When you look at the geographic distribution of the lighthouses, are certain countries more present than others? What's the pattern?

Enno de Boer: At the moment, you can take our research as representative in that way. But what we have seen is that we had an overproportionate share in China and in Asia, which at the beginning was a little bit surprising. We also have a big share in Europe. We have not so big a share in the US. That makes me very concerned.

Katy George: That is, unfortunately, not surprising. Because we've been tracking statistics around adoption of robotics and other digital capabilities. And the US is lagging Germany. It's lagging Asia. The places where the US should have a competitive advantage are places that the US is not actually finding a way to invest in order to create that advantage.

Simon London: We've mentioned 3-D printing as additive manufacturing in this conversation. How widespread is it? Where's it being adopted? A few years in, what is it good for?

Enno de Boer: 3-D printing is exciting, I think. I grew up with 3-D printing in prototyping, and it was inherently expensive. If you now look at it, it's penetrating mass markets. For example, we see that small parts in smartphones are now 3-D printed.

How do they do that economically? They print 100,000 of these parts in batches—then it's economically viable—because the parts are exactly designed and integrated in a way that was not possible before.

Katy George: But 3-D printing is not the only technology that's going to enable new levels of customization, for example, or new business models. We're talking with a clothing manufacturer that's setting up local production for customized clothing.

It's going to be using some of the same technology that already exists in sewing but taking pattern making, and cutting, and some of the other elements to a whole new level by creating flexible automation and digital control. There are a lot of different technologies that will be used in different combinations to achieve some of these benefits.

Simon London: The other technology that we've mentioned, without going into the detail, is Internet of Things sensors, broadly speaking. How important is IoT in this transformation?

Enno de Boer: Very important. IoT, if I take the analogy of the human body, is the nerve system. That's IoT. Then you have the sensors. The sensors get connected to the nervous system. Then you have the big brain. The big brain is the cloud.

IoT goes into the cloud. There, some intelligence is happening. Then you have the small brain. That's IoT at the edge. Artificial intelligence at the edge. So, a couple of repetitive things that need to happen in a distributed way.

Then you have the arms and legs. That's the automation in the end. That's how it all works together. And I think that's what makes me most excited about this field, is all these great technologies come together. Only if we put them together in the right way will we get the results, because they are all a piece of the puzzle.

Katy George: IoT is exciting in the kind of transformational impact it can have within the organism of a manufacturing site, for example. But it also—when you put IoT into the final product and can get customer usage data from it—it also creates incredible feedback loops to how you think about product design, how you think about marketing, how you think about production, and how you think about what's most important to consumers. How do you make a product more rugged for the way it's actually used? IoT will be game changing in many, many industries.

Simon London: When you're working with clients on these kinds of issues, trying to help them navigate this journey to full digital manufacturing, what are some of the hurdles that you see? What are some of the failure modes that come up over and again?

Katy George: The primary failure mode that we see, that exhibits in different ways, is something we're calling pilot purgatory—companies launch pilots around new technologies and somehow never get past that to actually scale and get the benefits of scaling.

The benefits of scaling are about scaling a use case beyond one small line to at least the scale of a plant or of a network. But also scaling in the sense of combining multiple use cases together to create the connectivity, the culture, the innovation, and the pace that a lighthouse plant exhibits.

There are a lot of reasons why companies never get past pilot purgatory. One is slow decision making, where there is a slow process for acquiring new technology or for completing a partnership. They're somehow able to get a pilot going but are slow to scale.

Another is having a backward-looking approach to return on investment [ROI]—not being able to allocate capital, even small amounts of capital, to scale something that has proved to work. Because they're always looking for some ROI hurdle that won't exist until they do scale multiple things together. Those are a couple of reasons why companies are getting stuck in this pilot purgatory. But it's something we're seeing many, many companies grapple with.

Simon London: How do you get out of it?

Enno de Boer: You need to figure out what you want to do with digital manufacturing. I get called in a lot where people say, "Tell us what this is." I ask back, "What problem do you want to solve?"

First, it's about the business problem you need to solve—and the impact. As Katy said earlier, there are several business dimensions and impact dimensions that you can take. You can be more agile. You can be faster to market. You can be more productive. You can mass personalize. But please define what you want to get out of it.

Katy George: I think one of the other failure modes is when companies get excited about "shiny new objects," in terms of new technologies, and take a technology-forward approach as opposed to what I would describe as a business-value-back approach. Embracing cool technology just for the sake of it, and trying to implement as much as possible, does not create any real business value.

You have to do the hard work of understanding what your competitive advantage is going to be, how you want to change it or enhance it using digital, and then work backward to see what the new capabilities are that you want to build with digital and advantaged-analytics capabilities.

Simon London: So, don't start with augmented-reality headsets, playing around with them and just trying to figure out, "What are we going to do with these?"

Katy George: Exactly right.

Enno de Boer: We need to stop with these bottom-up approaches where we tell our people, "OK, go innovate. Do a little bit here and there." We see this. And pilot purgatory means there are pilots all over the network that are not coordinated. You need to pull these all together. I think this is a time where leaders need to lean in. We need top management to lean in and decide which direction they want to take. Otherwise they will not be able to scale up.

Then if you have the strategy, you need to put some scale-up enablers in place. You need to put the right IT stack in place. You don't need to do that from the very beginning. Don't be scared that you need to invest a lot. The first use cases will work without, and they will be self-funding, so you can ease your way into this transformation. But at some point you will need to step back and innovate and modernize your IT stack.

You need to put a new people model in place. You need data scientists, yes. But that's not enough. You need translators. You need data engineers. You need all sorts of capabilities, and, most important, you need to upskill your management and your people so that they can work with these new capabilities.

You need to put a new data model in place and a new analytics model. All of these are scale-up enablers that are needed to go much faster, not incremental or use case by use case. But get the value at a low-increment cost.

Simon London: I'm reminded of a business book that was published many, many years ago—see if you remember it—called *Crossing the Chasm* [HarperCollins, 1991]. It was about tech companies and how they get to scale. It sounds like there's a

similar thing here. There are many companies with a lot of good and interesting pilots, but somehow you have to cross the chasm. It's at that point you probably need serious senior-management attention, and you need a strategy and investment. At a certain point, somebody just has to decide, "We're going to cross the chasm."

Enno de Boer: And it's not about talking anymore. It's not about playing around anymore. It's all tested out. We have a lot of proofs of concept out there. We have viable use cases out there. You don't need to play around anymore with these technologies. Figure out what problem you want to solve. Then figure out what the use cases are that can help you, and then scale them up.

Simon London: Super. Well, Katy and Enno, thank you very much for joining today.

Katy George: It was our pleasure.

Enno de Boer: It was a pleasure.

Simon London: And thanks, as always, to you, our listeners, for tuning in. To learn more about our research and work in manufacturing, technology, operations, and more, please visit McKinsey.com.

Katy George is a senior partner in McKinsey's New Jersey office, where **Enno de Boer** is a partner. **Simon London**, a member of McKinsey Publishing, is based in the Silicon Valley office.

Designed by Global Editorial Services